



The impact of acute stroke service centralisation: a time series evaluation

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THE IMPACT OF ACUTE STROKE SERVICE CENTRALISATION: A TIME SERIES EVALUATION

ABSTRACT

We evaluated the impact of centralisation of three acute stroke units into a single hyperacute stroke unit within a large urban and rural NHS Trust in North East England in June 2015. We performed retrospective interrupted time series analyses of 4,305 stroke patients admitted between 1 April 2013 and 31 December 2017 utilising data recorded for the Sentinel Stroke National Audit Programme.

Centralisation was associated with reductions in total length of inpatient stay (-4.9 days [95% CI: -8.1 to -1.7]). Time from admission to thrombolysis shortened by 26.0 minutes [95% CI: -40.0 to -12.1], and time from admission to brain imaging for thrombolysed patients improved by 16.2 minutes [95% CI: -22.0 to -10.4]. Time from stroke onset to hospital admission, mortality and dependency (as measured by median modified Rankin Scale) were unaffected by centralisation.

This study provides further evidence to support centralisation of acute stroke services in England.

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Comment [u1]: Amended to include the extra data analysed

Comment [u2]: Results updated with extra data analysed

INTRODUCTION

Randomised controlled trials and subsequent meta-analyses have clearly shown that stroke units reduce death and dependency.¹ Although stroke units are the cornerstone of evidence based stroke care, there is ongoing debate about whether acute stroke services should be provided locally with greater remote support or centrally with greater physical concentration of resources.²⁻⁶ Centralisation offers faster access to direct specialist care, neuroimaging and thrombolysis following arrival at hospital, but potentially at the expense of prolonged travel times.⁷ Achieving this balance is particularly important for patients who may be eligible to receive thrombolysis as the time from stroke onset to receiving this treatment is a key determinant of outcome.⁸

The National Health Service Five Year Forward View and proposed development of Urgent and Emergency Care Centres⁹ is driving review of acute stroke services across England. Centralisation of acute stroke services has been shown to reduce mortality and length of stay but results are not consistent across regional reorganisations.^{3, 10, 11} Data on impact of centralisation upon dependency post stroke are limited.¹²

Comment [u3]: Updated reference

We conducted an interrupted time series analysis to establish whether centralisation of multi-site acute into a single site hyperacute stroke service was associated with changes in key emergency care processes (scan time and thrombolysis delivery) and related outcomes (mortality, dependency and length of stay).

Comment [u4]: Amended to clarify our focus on hyperacute stroke care

METHODS

Study setting

Northumbria Healthcare NHS Foundation Trust (NHCT) provides secondary healthcare services to a rural and urban population of 500,000 in North East England (Figure 1).¹³ Prior to June 2015 emergency stroke care was provided in mixed acute stroke and rehabilitation units at three district general hospitals. All hospitals followed the same pre-hospital protocol

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via a single NHS Ambulance Trust and admitted stroke patients to a combined acute and rehabilitation unit from the A&E department or medical admissions unit, where they remained throughout their inpatient stay. Each hospital had a site-based stroke consultant and stroke nurse practitioner available 9am – 5pm Monday to Friday. An on call stroke consultant visited each of the three sites daily at weekends and telemedicine was used for out-of-hours thrombolysis decisions. A consultant opinion regarding thrombolysis was available 24 hours a day in a cross-site rota, but this was often a remote review with thrombolysis delivery by the A&E staff.

Comment [u5]: Clarified to emphasise shift from acute to hyperacute care

Comment [u6]: For clarification

In June 2015 Accident & Emergency Departments and all emergency services from the three acute hospitals were moved to a new purpose built hospital located in the south east of the catchment area - Northumbria Specialist Emergency Care Hospital (NSECH). NSECH provides consultant-led emergency care for the first 72 hours and those who need ongoing inpatient care are then transferred to one of the original three local hospitals. Geographical modelling using the postcodes of previous emergency admissions informed by population density and traffic conditions located NSECH where there would be no overall net increase in travel times for the population served. There was no intentional change to the Trust boundary or pre-hospital ambulance provision.

Northumbria Specialist Emergency Care Hospital has an 11-bed hyperacute stroke unit (HASU). A stroke consultant and nurse practitioner are available on site 12 hours per day, seven days per week and a stroke consultant provides an overnight telemedicine service. There are dedicated emergency CT and MRI scanners adjacent to the emergency department. Thrombectomy is available on an ad hoc basis at the regional neuroscience centre, which is located 10 miles away. A 24/7 thrombectomy service was not available during the study period and only a small number of patients (< 30) were referred for consideration of thrombectomy, and are not included in the current dataset.

Comment [u7]: Added in response to Reviewer 1 Comment 1

Study design, participants and data collection

We undertook an interrupted time series analysis covering 57 months (1 April 2013 to 31 December 2017). These data were already collected prospectively for the Sentinel Stroke National Audit Programme (SSNAP) database as part of routine clinical care and quality

improvement for all confirmed stroke admissions.¹² Patients with unknown stroke onset times or onset during sleep were excluded from the analysis of time from stroke onset to hospital arrival, but were included in all other analyses.

Discharge data used to calculate mortality, dependency and total length of-stay were calculated from the last hospital in the Trust that patients were discharged from (for example, if patients were transferred from NSECH to one of the district general hospitals, data from the district general hospitals were used).

Comment [u8]: Added for clarity

Statistical Analyses

Segmented regression models were used to establish the following outcomes: (i) time trends (change per month) for data prior to the centralisation (1 April 2013 to 30 June 2015); (ii) step change in levels for data immediately after centralisation (between 30 June 2015 and 1 July 2015); (iii) change in trends between data before and after centralisation; and (iv) time trends (change per month) for data after centralisation (1 July 2015 to 31 December 2017).

Comment [u9]: Added in response to Reviewer 1 Comment 2

Dummy variables were included in the regression model to assess for seasonal variation, and we considered the presence of positive or negative autocorrelation with the Durbin-Watson statistic (d) i.e. associations between consecutive monthly points in time series data which indicate that error terms (residuals) in regression models are not independent from one another and could confound results. In cases where $d > d_u$, or $4-d > d_u$ then it was concluded there was no statistical evidence of positive or negative autocorrelation respectively.¹⁴

RESULTS

Four thousand three hundred and five acute stroke patients were admitted to Northumbria Healthcare NHS Foundation Trust between 1 April 2013 and 31 December 2017: 2,045 prior to centralisation of acute stroke services and 2,260 post-centralisation. Five hundred and twenty eight (12.3%) patients received treatment with intravenous thrombolysis during this

Comment [u10]: Please note significant changes to the results following extra data analysed in response to Reviewer 1 Comment 3. There have been no further improvements in mortality or dependency, but there has been a significant improvement in length of stay.

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period (Supplementary Figure 1). No evidence of seasonality or autocorrelation was found in any of the segmented regression models.

The trend for the number of patients admitted in the pre-centralisation period was increasing significantly by 0.61 patients per month [95% CI: 0.1 to 1.2]. The number of admissions did not significantly change immediately after centralisation, and there was no significant trend for number of patients admitted over time in the post-centralisation period (Supplementary Table 1). There were no statistically significant changes in the proportion of patients who received thrombolysis across the study periods.

Table 1 and Supplementary Figure 2 show the pre-centralisation trend, the step change at the centralisation point, the change in trends between data before and after centralisation, and post-centralisation trends for inpatient mortality and dependency by modified Rankin Scale (mRS) at discharge for all acute stroke patients.¹⁵ There was no statistically significant impact of centralisation on mortality and dependency. Table 1 and Figure 2 demonstrated a statistically significant shortening of total length of stay immediately after centralisation of 4.9 days [95% CI: -8.1 to -1.7], which was subsequently sustained over time during the post-centralisation period.

Table 1: Impact of centralisation upon mortality, dependency* and length of stay

	% Patients who died as an inpatient	Median mRS at discharge	Median length of stay
Pre-centralisation trend (units/time)	-0.2%/month [95% CI: -0.3 to 0.0]**	0.00 mRS/month [95% CI: -0.0 to 0.0]	-0.1 days/month [95% CI: -0.2 to 0.1]
Step change immediately after centralisation (units)	0.5% [95% CI: -3.3 to 4.3]	-0.1 mRS [95% CI: -0.3 to 0.15]	-4.9 days [95% CI: -8.1 to -1.7]
Change in trends (units/time)	0.2 %/month [95% CI: -0.0 to 0.4]	0.0 mRS/month [95% CI: -0.0 to 0.0]	0.1 days/month [95% CI: -0.1 to 0.3]
Post-centralisation trend (units/time)	0.0 %/month [95% CI: -0.3 to 0.3]	-0.1 mRS/month [95% CI: -0.0 to 0.0]	-0.0 days [95% CI: -0.3 to 0.2]

*Dependency as measured by the modified Rankin Scale¹⁵ (mRS): 0 – no symptoms; 1 – no significant disability despite symptoms, able to carry out all usual duties and activities; 2 – slight disability, unable to carry out all previous activities, but able to look after own affairs without assistance; 3 – moderate disability, requiring some help, but able to walk without assistance; 4 – moderately severe disability, unable to walk without assistance and unable to attend own bodily needs without assistance; 5 – severe disability, bedridden, incontinent and requiring constant nursing care; 6 – dead.

**95% Confidence Intervals. Statistical significance was designated as $p < 0.05$ where confidence intervals were borderline at 1 decimal place.

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The time of stroke onset was known for 3,168 (73.6%) patients (Figure 3a). The prolonged times between stroke onset and admission observed between 1 July and 30 November 2013 were due to an anomalous period of ambulance diversion. Interrupted time series analyses are particularly sensitive to outliers.¹⁶ The results of analyses with and without outlying months included are shown in Supplementary Table 1. After excluding the outlying months, time from stroke onset to admission did not significantly change across the study periods.

Time from admission to brain imaging did not change across the whole cohort (Supplementary Table 2), but those who received thrombolysis had shortened admission-to-scan times immediately after centralisation of 16.2 minutes [95% CI: -22.0 to -10.4]; which was subsequently sustained over time during the post-centralisation period (Supplementary Figure 3).

There was statistically significant (step change) improvement immediately after centralisation in time from admission to thrombolysis by 26.0 minutes [95% CI: -39.9 to -12.1], which was subsequently sustained over time during the post-centralisation period (Supplementary Table 2). However, this improvement in time trend during post-centralisation was non-significant when time from stroke onset to thrombolysis was analysed (-21.3 minutes [95% CI: -48.9 to 6.3]) (Figure 3b).

In Supplementary Table 3, we have provided published Sentinel Stroke National Audit Programme results comparing Northumbria Healthcare NHS Foundation Trust against the national averages for time from admission to scan and time from admission to thrombolysis for the duration of the study.¹⁷ These data show that door-to-needle times were generally longer than the national average prior to centralisation, but post-centralisation they have remained shorter than the national average. Case-mix data are available in Supplementary Table 4.

DISCUSSION

Regional centralisation of three acute stroke services in a large urban and rural NHS Trust in North East England was associated with a statistically significant reduction in length of stay.

Mortality and dependency outcomes were unchanged. Immediate improvements after centralisation were identified in door-to-needle times and door-to-scan times for patients who received thrombolysis which were sustained over time during the post-centralisation period.

Comment [u11]: To reflect updated results

The parameter estimates in the segmented regression models take into account the underlying time trends prior to centralisation. Therefore, statistically significant changes in time trends after centralisation are over and above any background time trends. This increases the confidence that the estimates of effect we identified can be attributed to the impact of centralisation.

Comment [u12]: In response to Reviewer 1 comment 2

A previous modelling exercise of acute stroke service reorganisation within North East England had shown a positive trade-off between longer ambulance journeys and improved thrombolysis delivery following theoretical redirection from eight local hospitals to two large HASUs.¹⁸ This assumed that ambulance resources and geographical boundaries remained constant. Following the opening of Northumbria Specialist Emergency Care Hospital, there was no significant net change in the time between stroke onset and arrival at hospital. However there may have been variable effects for subgroups within the population due to changes in travel times to hospital from different localities and shifts in ambulance service provision to achieve response targets after centralisation. A more in-depth analysis of stroke onset-to-admission times should be explored in the future, which would require additional ambulance operational data and comparisons with other sites to consider the impact of chronological trends in service demand and performance.

Comment [u13]: To reflect updated results

Earlier scanning has also been shown to improve outcomes for acute stroke patients.¹⁹ Door-to-scan times were unchanged following centralisation for all patients but significantly reduced for those receiving thrombolysis, reflecting early coordinated clinical triage assessments. The observed statistically significant improvement in length of stay reflects the benefit from focussing on forward care planning at an early stage with twice daily multidisciplinary team discussion about potential discharges, including weekends and good access to investigations e.g. MRI and Doppler.

Comment [u14]: To reflect updated results

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Intravenous thrombolysis is a time dependent treatment and the sooner it is delivered the greater the benefit.²⁰ Minimising transport delays and efficient paramedic and hospital assessments with prompt delivery of imaging and thrombolysis are key to optimising the benefits of this treatment.^{21,22} Thrombolysis both before and after centralisation was predominantly delivered by a consultant stroke physician and stroke nurse practitioner. Increased on site availability of these specialists likely contributed to further improvement in rapid thrombolysis assessments, to an extent over and above to the greater experience that comes with higher volumes of patients being thrombolysed in a single centre.²³ Acute radiology facilities (CT and MRI) were located next to the Accident and Emergency Department enabling quick access to scanning with pre-alert from paramedics. A streamlined care pathway contributed to the reduction in door-to-needle time.

Methodological considerations

An interrupted time series design enabled us to establish the effects of centralisation of stroke services above and beyond any baseline time trends.¹⁶ An interrupted time series analysis ideally requires 10 or more pre-intervention time points¹⁶: we included data for 27 months before and 30 months after centralisation. Other features of a robust analysis were: inclusion of continuous variables; consideration of homoscedasticity; a lack of autocorrelation; and the normal distribution of residuals.²⁴

Comment [u15]: To include extra data analysed

Interrupted time series analysis analyses are able to control for potential confounders provided that they did not also change at the point of intervention.¹⁶ We have not identified any confounding factors that changed at the point of centralisation which may have impacted upon the results.

Comparison with other studies

Previous UK studies have reported before and after study data and difference-in-differences relating to reorganisation of acute stroke services.^{3, 10-12} This is the first time that an interrupted time series has been reported, which addresses potential methodological drawbacks of the latter study designs. Our results are consistent with previous studies that have demonstrated that when properly implemented, a centralised model of stroke care

can achieve shorter length of stay and improve key time metrics compared to local service provision.^{3, 10-12}

Comment [u16]: To reflect updated results

In London, stroke care for a population of 8.17 million was reorganised into eight HASUs for all suspected stroke admissions. After a period of up to 72 hours, patients who required further stroke specialist care were transferred to one of 24 local stroke units.²⁵ This major reorganisation led to an improvement in 90-day mortality of 1.1% [95%CI: -2.1 to -0.1] above that seen in the rest of England, including reduced hospital stay by a mean of 1.4 days [95% CI: -2.3 to 0.5], contributing to significant cost savings.^{3, 10}

The Greater Manchester (population 2.6 million) reorganisation was less radical in that services were only centralised for patients presenting within the time window for potential thrombolysis. Patients presenting less than four hours after suspected stroke were taken to one of two Primary Stroke Centres (offering thrombolysis for 12 hours a day, 5 days a week) or alternatively to one Comprehensive Stroke Centre (offering hyperacute stroke and regional neuroscience services 24 hours a day, 7 days a week). Patients were then discharged or transferred to their local stroke unit within 72 hours. Patients presenting outside of four hours were taken to one of 10 local District Stroke Centres (DSC).²⁵ There was no improvement in mortality but length of stay was reduced by a mean of 2.0 days [95% CI: -2.8 to -1.2].¹⁰

The context of our study is positioned between a very local and regional setting as we report the reorganisation of three sites within a single large NHS Trust without crossing organisational boundaries. Unlike previous reported stroke service reconfigurations, this centralisation was part of comprehensive restructuring of all acute services within the region: Northumbria Specialist Emergency Care Hospital is the first purpose built Emergency Care Hospital in England.²⁶ Our findings are consistent with the results from London and Greater Manchester, which also found that centralisation improved length of hospital stay. We are also able to provide evidence that centralisation improved door-to-needle times for patients who received thrombolysis. We did not find any statistically significant difference in mortality or dependency following centralisation.

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Strengths and limitations of this study

A major strength of our study was that stroke care was provided by the same stroke consultants and nurse practitioners before and after centralisation. We also maintained consistency of measurements across the whole study period with a standardised approach to data collection by the same healthcare professional workforce across the study period. The Sentinel Stroke National Audit Programme cross-references locally submitted cases via the Office of National Statistics to ensure high levels of ascertainment for stroke admissions and openly reports data completeness.¹²

We chose to undertake an interrupted time series study because it is an efficient but strong methodological design which employs readily available data.²⁷ A randomised controlled trial would be the gold standard to assess the impact of centralisation of stroke services upon outcomes of care. However, a multicentre trial to evaluate the centralisation of stroke services would be: significantly more expensive; logistically challenging; take longer to perform; and carries its own ethical dilemmas.²⁸

We used health status at discharge from hospital as a key outcome measure. Including longer-term outcomes could have strengthened the study but these data were not available. Additionally, a single group interrupted time series analysis does not correct for any confounding factors which also changed at the centralisation point, which a comparative interrupted time series analysis can achieve.²⁹

Our focus was on aspects of service delivery which could be particularly influenced by a change in emergency care processes within the first hour of hospital admission, but a larger study could consider the impact of other acute care processes such as swallowing assessment and provision of fluid support.

Comment [u18]: In response to Reviewer
1 Comment 1

Implications

Acute stroke care is one of five specialist services priorities for Urgent and Emergency Care Networks in England.³⁰ Acute stroke services are delivered across 155 sites³¹ in England and many are struggling to provide 24/7 stroke specialist care. Services with higher rates of stroke admissions have previously been shown to be both more efficient and more

effective.²³ However, centralisation of services is a controversial topic for both patients, communities and politicians³² but this study provides further robust research evidence to support the case for change.

Conclusion

We found evidence that centralisation of three acute stroke units within a single NHS Trust in North East England improved door-to-needle times, and reduced length of inpatient stay. This supports the ongoing re-organisation of emergency care for stroke patients as an NHS priority.

Comment [u19]: To reflect updated results

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Legends

Figure 1: Map of population density across Northumberland and Tyne & Wear counties. Northumbria Healthcare Trust boundary highlighted in red. Modified from a figure published by the Office for National Statistics.¹³ Contains National Statistics data and Ordnance Survey data © Crown copyright and database right 2013. Also contains public sector information licensed under the Open Government Licence v3.0.

Figure 2: Total length of hospital stay from first admission to last discharge (mean days). Centralisation month (June 2015) highlighted in grey.

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Figure 3b (bottom): Time from stroke onset to thrombolysis (top) and from hospital admission to thrombolysis (bottom) expressed as median minutes. Centralisation month (June 2015) highlighted in grey.

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Supplementary Figure 3: Time from hospital admission to CT head scan for all patients (top) and for thrombolysed patients (bottom) expressed as median minutes. Centralisation month (June 2015) highlighted in grey.

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Supplementary Table 1: Number of stroke admissions, proportion thrombolysed, and impact of centralisation upon time from stroke onset to admission

	Monthly number of stroke admissions	Monthly proportion of patients thrombolysed	Onset-to-door time (from Apr 13)	Onset-to-door time (from Dec 13)
Number of patients summed across all months	N = 4,305	N = 528	N = 3,168	N = 2,733
Pre-centralisation trend (<i>units/time</i>)	0.6 patients/month [95% CI: 0.1 to 1.1]	0.1 %/month [95% CI: -0.1 to 0.4]	-5.2 mins/month [95% CI: -9.6 to -0.8]	-0.5 mins/month [95% CI: -5.5 to 4.5]
Step change immediately after centralisation (<i>units</i>)	-3.3 patients [95% CI: -14.2 to 7.7]	-4.1 % [95% CI: -8.5 to 0.3]	60.9 mins [95% CI: -33.7 to 155.5]	36.4 mins [95% CI: -32.7 to -105.6]
Change in trends (<i>units/time</i>)	-0.9 patients/month [95% CI: -1.6 to -0.3]	-0.1 %/month [95% CI: -0.4 to 0.2]	7.6 mins/month [95% CI: 1.8 to 13.4]	2.9 mins/month [95% CI: -2.7 to 8.5]
Post-centralisation trend (<i>units/time</i>)	-0.3 patients/month [95% CI: -1.2 to 0.5]	0.0 %/month [95% CI: -0.3 to 0.4]	2.4 mins/month [95% CI: -4.9 to 9.7]	2.4 mins/month [95% CI: -5.1 to 10.0]
R-squared:	-	-	14.5%	30.8%

Supplementary Table 2: Impact of centralisation upon door-to-scan and thrombolysis times

	Door-to-scan time (all patients)	Door-to-scan time (thrombolysed only)	Door-to-needle time (thrombolysed only)	Onset-to-needle time (thrombolysed only)
Number of patients summed across all months	N = 4,305	N = 528	N = 528	N = 525
Pre-centralisation trend (<i>units/time</i>)	-0.0 mins/month [95% CI: -0.8 to 0.8]	0.1 mins/month [95% CI: -0.2 to 0.3]	0.1 mins/month [95% CI: -0.5 to 0.8]	0.4 mins/month [95% CI: -0.9 to 1.7]
Step change immediately after centralisation (<i>units</i>)	-3.1 mins [95% CI: -20.5 to 14.4]	-16.2 mins [95% CI: -22.0 to -10.4]	-26.0 mins [95% CI: -40.0 to -12.1]	-21.3 mins [95% CI: -48.9 to 6.3]
Change in trends (<i>units/time</i>)	-0.2 mins/month [95% CI: -1.3 to 0.9]	-0.0 mins/month [95% CI: -0.4 to 0.3]	-0.1 mins/month [95% CI: -1.0 to 0.7]	0.2 mins/month [95% CI: -1.5 to 2.0]
Post-centralisation trend (<i>units/time</i>)	-0.3 mins/month [95% CI: -1.6 to 1.1]	0.1 mins/month [95% CI: -0.4 to 0.5]	-0.0 mins/month [95% CI: -1.1 to 1.1]	0.6 mins/month [95% CI: -1.5 to 2.7]

Supplementary Table 3: Quarterly door-to-needle (thrombolysis patients) and door-to-scan times (all patients) from published SSNAP data¹⁷

	Hexham	Wansbeck	N. Tyneside	NSECH	National
Jul-Sep 13					
Door-to-scan (mins)	156	67	120.5	-	86
Door-to-needle (mins)	57	50	50		59
Oct-Dec 13					
Door-to-scan (mins)	70	70	90	-	83
Door-to-needle (mins)	49	62	64		58
Jan-Mar 14					
Door-to-scan (mins)	46	52	122	-	78
Door-to-needle (mins)	69	54	65		56
Apr-Jun 14					
Door-to-scan (mins)	82	101	84	-	79
Door-to-needle (mins)	136	83	66		57
Jul-Sep 14					
Door-to-scan (mins)	83	57	87	-	75
Door-to-needle (mins)	73	50	64		56
Oct-Dec 14					
Door-to-scan (mins)	85	74	106	-	65
Door-to-needle (mins)	67	42	50		55
Jan-Mar 15					
Door-to-scan (mins)	53	81	102	-	72
Door-to-needle (mins)	47	61	74		56
Apr-Jun 15					
Door-to-scan (mins)	62	67	86	-	69
Door-to-needle (mins)	81	56	60		55
Jul-Sep 15					
Door-to-scan (mins)	-	-	-	72	66
Door-to-needle (mins)				34	53
Oct-Dec 15					
Door-to-scan (mins)	-	-	-	95	64
Door-to-needle (mins)				39	55
Jan-Mar 16					
Door-to-scan (mins)	-	-	-	88	64
Door-to-needle (mins)				43	54
Apr-Jul 16					
Door-to-scan (mins)	-	-	-	63	59
Door-to-needle (mins)				38	52

	Hexham	Wansbeck	N. Tyneside	NSECH	National
Aug-Nov 16					
Door-to-scan (mins)	-	-	-	80	59
Door-to-needle (mins)				33	51
Dec-Mar 17					
Door-to-scan (mins)	-	-	-	53	55
Door-to-needle (mins)				38	52
Apr-Jul 17					
Door-to-scan (mins)	-	-	-	69	55
Door-to-needle (mins)				48	50

* *Most recent results available at time of submission*

Supplementary Table 4: Casemix pre- and post-centralisation

	Pre- centralisation	SD/IQR*	Post- centralisation	SD/IQR*
Mean age at presentation	74.6	SD: 12.9	74.9	SD: 12.5
Gender (% male)	50.0%		50.9%	
Ethnicity (% British)	99.0%		99.5%	
Hypertension (%)	56.4%		52.8%	
Diabetes (%)	17.4%		17.8%	
Atrial fibrillation (%)	19.9%		16.7%	
Congestive heart failure (%)	2.0%		3.2%	
Prior TIA/stroke (%)	29.2%		25.3%	
Stroke type (% infarct)	88.1%		88.2%	
Median mRS pre-stroke	1.00	IQR: 2	1.00	IQR: 2
Median NIHSS on arrival	4.00	IQR: 10	4.00	IQR: 8

*SD = standard deviation (reported for means), IQR = interquartile range (reported for medians)

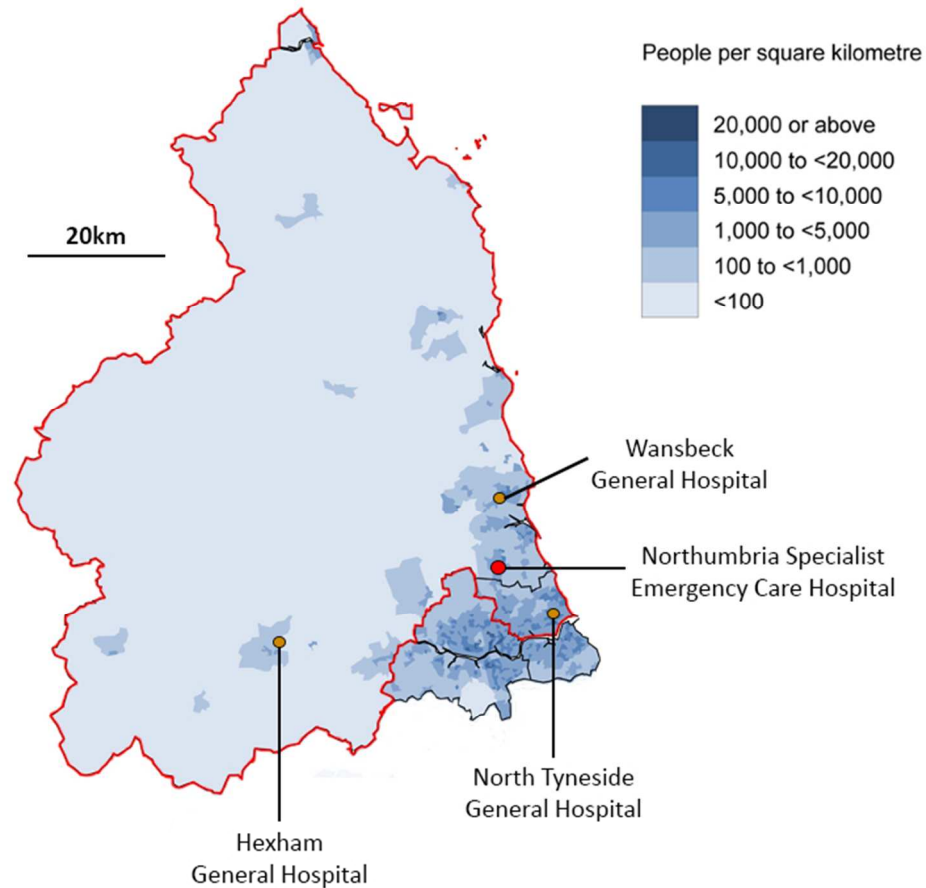


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107x99mm (180 x 180 DPI)

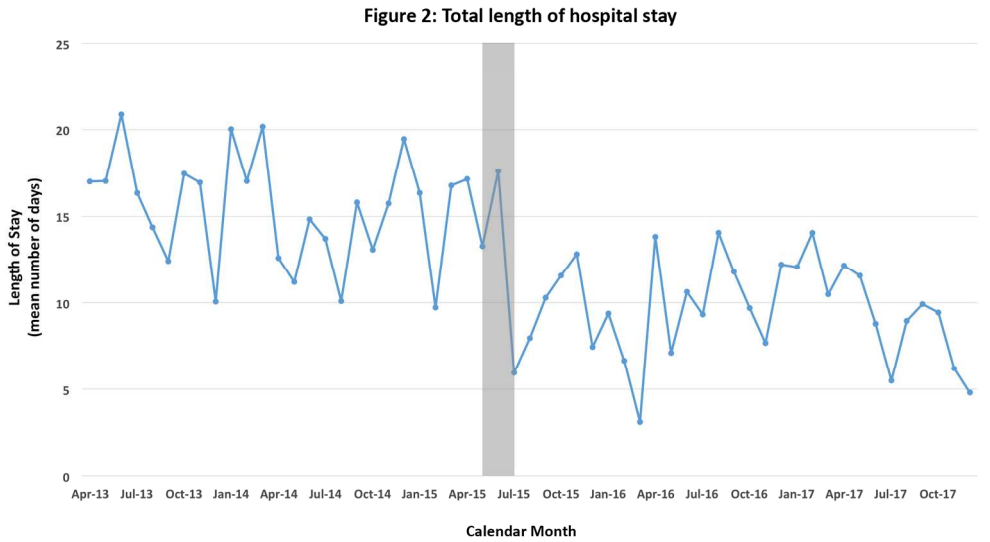


Figure 2: Total length of hospital stay from first admission to last discharge (mean days). Centralisation month (June 2015) highlighted in grey.

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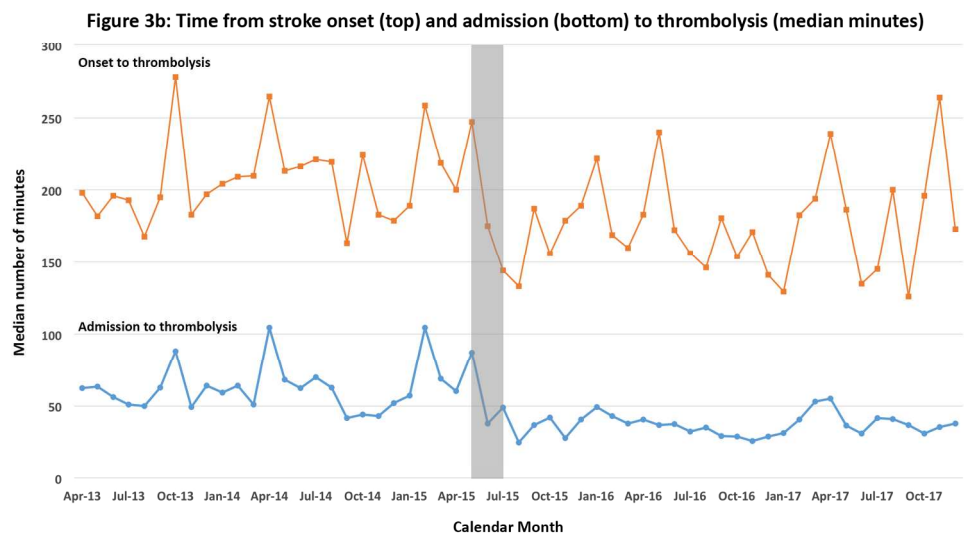
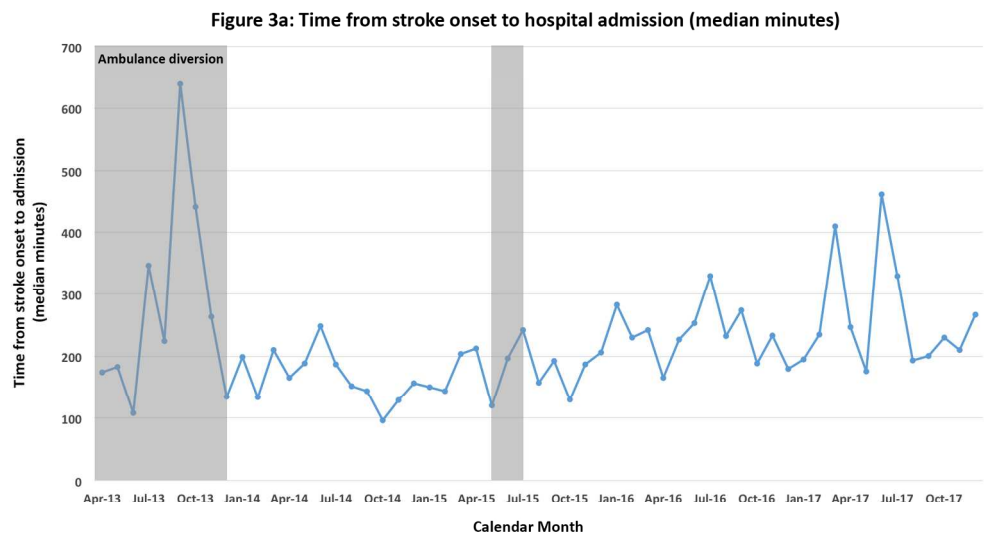
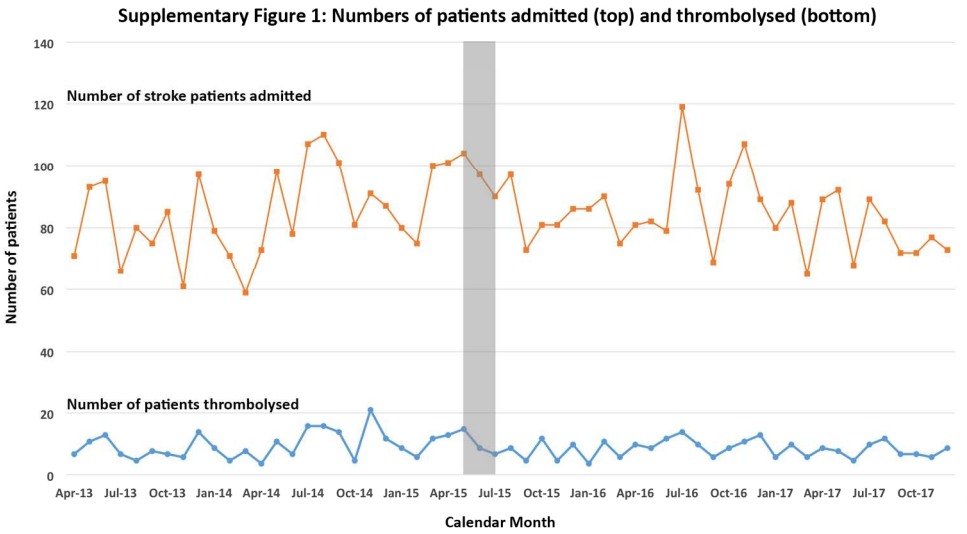


Figure 3a (top): Time from stroke onset to hospital admission (median minutes). Period of ambulance diversion due to CT scanner maintenance highlighted in grey at the left of the graph. Centralisation month (June 2015) highlighted in grey.

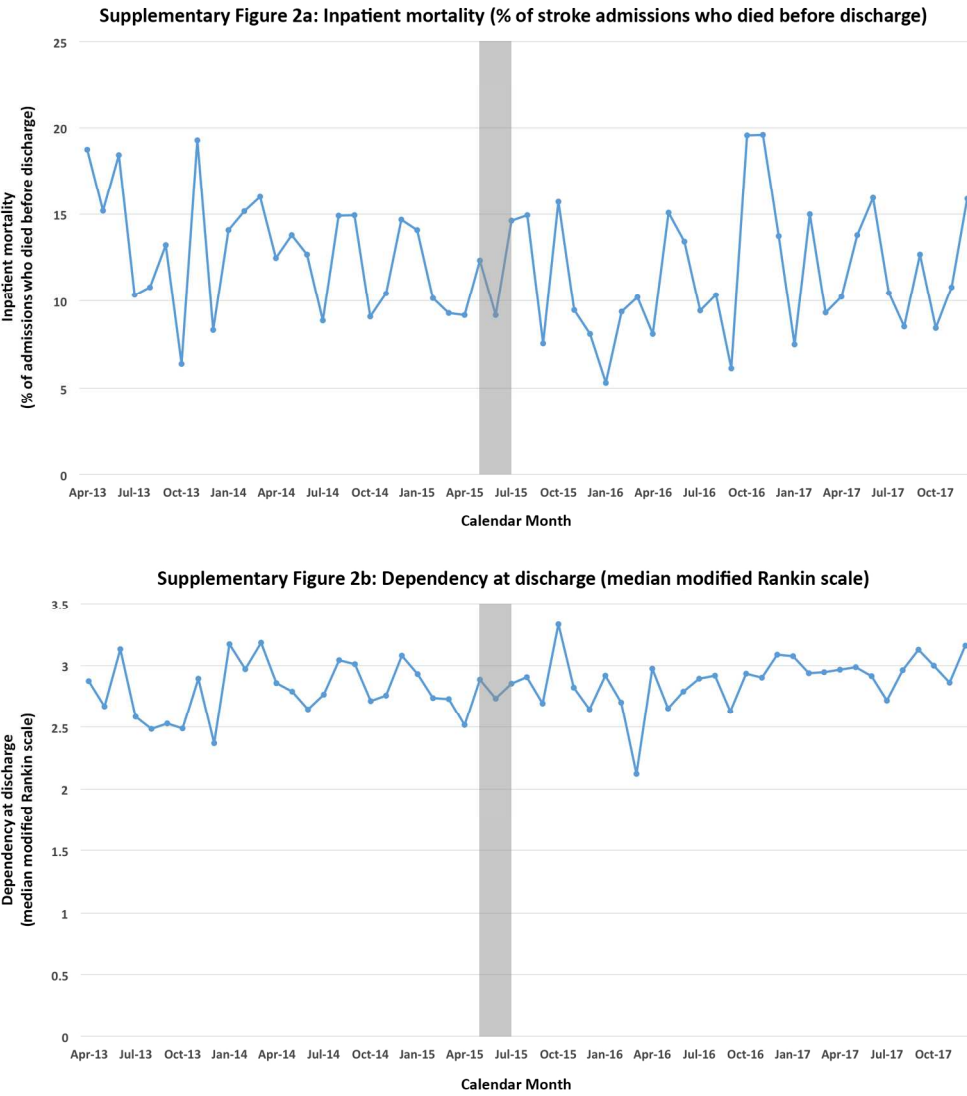
Figure 3b (bottom): Time from stroke onset to thrombolysis (top) and from hospital admission to thrombolysis (bottom) expressed as median minutes. Centralisation month (June 2015) highlighted in grey.

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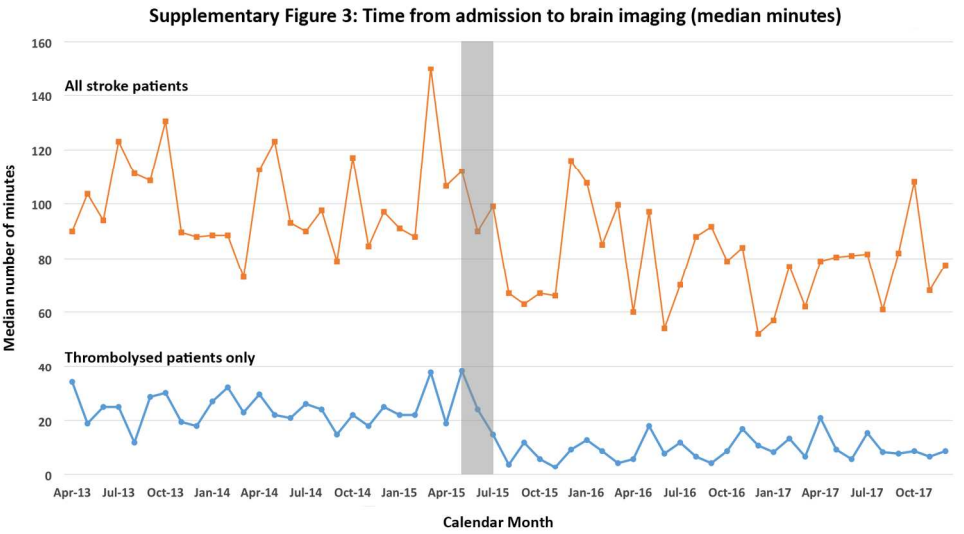
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Supplementary Figure 2b (bottom): Dependency at discharge for all acute stroke admissions expressed as modified Rankin Scale. Centralisation month (June 2015) highlighted in grey.

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Supplementary Figure 3: Time from hospital admission to CT head scan for all patients (top) and for thrombolysed patients (bottom) expressed as median minutes. Centralisation month (June 2015) highlighted in grey.

343x204mm (150 x 150 DPI)